<u>**VERSION WITH MARKINGS TO SHOW CHANGES MADE**</u>

IN THE SPECIFICATION:

The paragraph beginning on page 8, line 3 has been replaced with the following paragraph. Note that the only change here is the insertion of a space before the sentence beginning with the phrase "Fast fading...":

Loss due to slow fading includes shadowing due to clutter blockage (sometimes included in Lp). Fast fading is composed of multipath reflections which cause: 1) delay spread; 2) random phase shift or Rayleigh fading; and 3) random frequency modulation due to different Doppler shifts on different paths.

The paragraph beginning on page 10, line 3 through page 10, line 20 has been replaced with the following paragraphs:

It is an objective of the present invention to provide a system and method for to wireless telecommunication systems for accurately locating people and/or objects in a cost effective manner. Additionally, it is an objective of the present invention to provide such location capabilities using the measurements from wireless signals communicated between mobile stations and a network of base stations, wherein the same communication standard or protocol is utilized for location as is used by the network of base stations for providing wireless communications with mobile stations for other purposes such as voice communication and/or visual communication (such as text paging, graphical or video communications). Related objectives for <u>various embodiments of</u> the present invention include providing a system and method that:

(1.1)   can be readily incorporated into existing commercial wireless telephony systems with few, if any, modifications of a typical telephony wireless infrastructure;

(1.2)   can use the native electronics of typical commercially available<u>, or likely to be available,</u> telephony wireless mobile stations (e.g., handsets) as location devices;

(1.3)   can be used for effectively locating people and/or objects wherein there are few (if any) line-of-sight wireless receivers for receiving location signals from a mobile station (herein also denoted MS);

(1.4)   can be used not only for decreasing location determining difficulties due to multipath phenomena but in fact uses such multipath for providing more accurate location estimates;

(1.5)   can be used for integrating a wide variety of location techniques in a straight-forward manner; [and]

(1.6)   can substantially automatically adapt and/or (re)train and/or (re)calibrate itself according to changes in the environment and/or terrain of a geographical area where the present invention is utilized;

(1.7)   can utilize a plurality of wireless location estimators based on different wireless location technologies (e.g., GPS location techniques, terrestrial base station signal timing techniques for triangulation and/or trilateration, wireless signal angle of arrival location techniques, techniques for determining a wireless location within a building, techniques for determining a mobile station location using wireless location data collected from the wireless coverage area for, e.g., location techniques using base station signal coverage areas, signal pattern matching location techniques and/or stochastic techniques), wherein each such estimator may be activated independently of one another, whenever suitable data is provided thereto and/or certain conditions, e.g., specific to the estimator are met;

(1.8)   can provide a common interface module from which a plurality of the location estimators can be activated and/or provided with input;

(1.9)   provides resulting mobile station location estimates to location requesting applications (e.g., for 911 emergency, the fire or police departments, taxi services, vehicle location, etc.) via an output gateway, wherein this gateway:

> (a)   routes the mobile station location estimates to the appropriate location application(s) via a communications network such as a wireless network, a public switched telephone network, a short messaging service (SMS), and the Internet,
>
> (b)   determines the location granularity and representation desired by each location application requesting a location of a mobile station, and/or
>
> (c)   enhances the received location estimates by, e.g., performing additional processing such as "snap to street" functions for mobile stations known to reside in a vehicle.

The paragraph beginning on page 11, line 15 has been replaced with the following paragraph:

(3.3)   The term, "infrastructure", denotes the network of telephony communication services, and more particularly, that portion of such a network that receives and processes wireless communications with

wireless mobile stations. In particular, this infrastructure includes telephony wireless base stations (BS) such as those for radio mobile communication systems based on CDMA, AMPS, NAMPS, TDMA, and GSM wherein the base stations provide a network of cooperative communication channels with an air interface with the MS, and a conventional telecommunications interface with a Mobile Switch Center (MSC). Thus, an MS user within an area serviced by the base stations may be provided with wireless communication throughout the area by user transparent communication transfers (i.e., "handoffs") between the user's MS and these base stations in order to maintain effective telephony service. The mobile switch center (MSC) provides communications and control connectivity among base stations and the public telephone network 124.

The paragraph beginning on page 12, line 6 has been replaced with the following paragraphs:

The present invention relates to a wireless mobile station location system, and in particular, various subsystems related thereto such as a wireless location gateway, and the combining or hybriding of a plurality of wireless location techniques.

Regarding a wireless location gateway, this term refers to a communications network node whereat a plurality of location requests are received for locating various mobile stations from various sources (e.g., for E911 requests, for stolen vehicle location, for tracking of vehicles traveling cross country, etc.), and for each such request and the corresponding mobile station to be located, this node: (a) activates one or more wireless location estimators for locating the mobile station, (b) receives one or more location estimates of the mobile station from the location estimators, and (c) transmits a resulting location estimate(s) to, e.g., an application which made the request. Moreover, such a gateway typically will likely activate location estimators according to the particulars of each individual wireless location request, e.g., the availability of input data needed by particular location estimators. Additionally, such a gateway will typically have sufficiently well defined uniform interfaces so that such location estimators can be added and/or deleted to, e.g., provide different location estimators for performing wireless location different coverage areas.

The present invention encompasses such wireless location gateways. Thus, for locating an identified mobile station, the location gateway embodiments of the present invention may activate one or more of a plurality of location estimators depending on, e.g., (a) the availability of particular types of wireless location data for locating the mobile station, and (b) the location

estimators accessable by the location gateway. Moreover, a plurality of location estimators may be activated for locating the mobile station in a single location, or different ones of such location estimators may be activated to locate the mobile station at different locations. Moreover, the location gateway of the present invention may have incorporated therein one or more of the location estimators, and/or may access geographically distributed location estimators via requests through a communications network such as the Internet.

In particular, the location gateway of the present invention may access, in various instances of locating mobile stations, various location estimators that utilize one or more of the following wireless location techniques:

(a)   A GPS location technique such as, e.g., one of the GPS location techniques as described in the Background section hereinabove;

(b)   A technique for computing a mobile station location that is dependent upon geographical offsets of the mobile station from one or more terrestrial transceivers (e.g., base stations of a commercial radio service provider). Such offsets may be determined from signal time delays between such transceivers and the mobile station, such as by time of arrival (TOA) and/or time difference of arrival (TDOA) techniques as is discussed further hereinbelow. Moreover, such offsets may be determined using both the forward and reverse wireless signal timing measurements of transmissions between the mobile station and such terrestrial transceivers. Additionally, such offsets may be directional offsets, wherein a direction is determined from such a transceiver to the mobile station;

(c)   Various wireless signal pattern matching, associative, and/or stochastic techniques for performing comparisons and/or using a learned association between:

(i) characteristics of wireless signals communicated between a mobile station to be located and a network of wireless transceivers (e.g., base stations), and

(ii) previously obtained sets of characteristics of wireless signals (from each of a plurality of locations), wherein each set was communicated, e.g., between a network of transceivers (e.g., the

fixed location base stations of a commercial radio service provider), and, some one of the mobile stations available for communicating with the network;

(d)   Indoor location techniques using a distributed antenna system;

(e)   Techniques for locating a mobile station, wherein, e.g., wireless coverage areas of individual fixed location transceivers (e.g., fixed location base stations) are utilized for determining the mobile station's location (e.g., intersecting such coverage areas for determining a location);

(f)   Location techniques that use communications from low power, low functionality base stations (denoted "location base stations"); and

(g)   Any other location techniques that may be deemed worthwhile to incorporate into an embodiment of the present invention.

Accordingly, some embodiments of the present invention may be viewed as platforms for integrating wireless location techniques in that wireless location computational models (denoted "first order models" or "FOMs" hereinbelow) may be added and/or deleted from such embodiments of the invention without changing the interface to further downstream processes. That is, one aspect of the invention is the specification of a common data interface between such computational models and subsequent location processing such as processes for combining of location estimates, tracking mobile stations, and/or outputting location estimates to location requesting applications.

Moreover, it should be noted that the present invention also encompasses various hybrid approaches to wireless location, wherein various combinations of two or more of the location techniques (a) through (g) immediately above may be used in locating a mobile station at substantially a single location. Thus, location information may be obtained from a plurality of the above location techniques for locating a mobile station, and the output from such techniques can be synergistically used for deriving therefrom an enhanced location estimate of the mobile station.

It is a further aspect of the present invention that it may be used to wirelessly locate a mobile station: (a) from which a 911 emergency call is performed, (b) for tracking a mobile station (e.g., a truck traveling across country), (c) for routing a mobile station, and (d) locating

people and/or animals, including applications for confinement to (and/or exclusion from) certain areas.

It is a further aspect of the present invention that it [In particular, such a wireless mobile station location system] may be decomposed into: (i) a first low level wireless signal processing subsystem for receiving, organizing and conditioning low level wireless signal measurements from a network of base stations cooperatively linked for providing wireless communications with mobile stations (MSs); and (ii) a second high level signal processing subsystem for performing high level data processing for providing most likelihood location estimates for mobile stations.

The paragraph beginning on page 12, line 11 has been replaced with the following paragraph:

Thus[More precisely], the present invention may be considered as [is]a novel signal processor that includes at least the functionality for the high signal processing subsystem mentioned hereinabove. Accordingly, assuming an appropriate ensemble of wireless signal measurements characterizing the wireless signal communications between a particular MS and a networked wireless base station infrastructure have been received and appropriately filtered of noise and transitory values (such as by an embodiment of the low level signal processing subsystem disclosed in a copending PCT patent application PCT/US97/15933 titled, "Wireless Location Using A Plurality of Commercial Network Infrastructures," by F. W. LeBlanc et al.,[and the present applicant(s); this copending patent application] filed September 8, 1997 from which U.S. Patent 6,236,365, filed July 8, 1999 is the U.S. national counterpart; these two references being herein fully incorporated by reference), the present invention uses the output from such a low level signal processing system for determining a most likely location estimate of an MS.

The paragraph beginning on page 12, line 19 (and ending on this same line 19) has been replaced with the following paragraph:

That is, once the following steps are appropriately performed (e.g., by the LeBlanc [copending application] U.S. Patent 6,236,365):

The paragraph beginning on page 12, line 28 has been replaced with the following paragraph:

(4.3)   providing the composite signal characteristic values to one or more MS location hypothesizing computational models (also denoted herein as "first order models" and also "location estimating models"), wherein each such model subsequently determines one or more initial estimates of the location of the target MS based on, for example, the signal processing techniques 2.1 through 2.3 above. Moreover, each of the models output MS location estimates having substantially identical data structures (each such data structure denoted a "location hypothesis"). Additionally, each location hypothesis may also include[s] a confidence value indicating the likelihood or probability that the target MS whose location is desired resides in a corresponding location estimate for the target MS;

The paragraph beginning on page 13, line 14 has been replaced with the following paragraph:

Referring now to (4.3) above, the filtered and aggregated wireless signal characteristic values are provided to a number of location hypothesizing models (denoted First Order Models, or FOMs), each of which yields a location estimate or location hypothesis related to the location of the target MS. In particular, there are location hypotheses for both providing estimates of where the target MS is_likely to be and where the target MS is not likely to be. Moreover, it is an aspect of the present invention that confidence values of the location hypotheses are provided as a continuous range of real numbers from, e.g., -1 to 1, wherein the most unlikely areas for locating the target MS are given a confidence value of -1, and the most likely areas for locating the target MS are given a confidence value of 1. That is, confidence values that are larger indicate a higher likelihood that the target MS is in the corresponding MS estimated area, wherein [1] -1 indicates that the target MS is absolutely NOT in the estimated area, 0 indicates a substantially neutral or unknown likelihood of the target MS being in the corresponding estimated area, and 1 indicates that the target MS is absolutely within the corresponding estimated area.

The paragraph beginning on page 15, line 22 has been replaced with the following paragraph:

It is a further aspect of the present invention that the personal communication system (PCS) infrastructures currently being developed by telecommunication providers offer an appropriate localized infrastructure base upon which to build various personal location systems (PLS) employing the present invention and/or utilizing the techniques disclosed herein. In particular, the present invention is especially suitable for the location of people and/or objects using code division multiple access (CDMA) wireless infrastructures, although other wireless infrastructures, such as, time division multiple access (TDMA) infrastructures and GSM are also contemplated. Note that CDMA personal communications

systems are described in the Telephone Industries Association standard IS-95, for frequencies below 1 GHz, and in the Wideband Spread- Spectrum Digital Cellular System Dual-Mode Mobile Station-Base Station Compatibility Standard, for frequencies in the 1.8-1.9 GHz frequency bands, both of which are incorporated herein by reference. Furthermore, CDMA general principles have also been described, for example, in U. S. Patent 5,109,390, to Gilhausen, et al, filed November 7, 1989, and CDMA Network Engineering Handbook by Qualcomm, Inc., [ ]each of which is also incorporated herein by reference.

The paragraph beginning on page 16, line 6 has been replaced with the following paragraph:

As mentioned [in (1.7) and]in the discussion of classification FOMs above, the present invention can substantially automatically retrain and/or recalibrate itself to compensate for variations in wireless signal characteristics (e.g., multipath) due to environmental and/or topographic changes to a geographic area serviced by the present invention. For example, in one embodiment, the present invention optionally includes low cost, low power base stations, denoted location base stations (LBS) above, providing, for example, CDMA pilot channels to a very limited area about each such LBS. The location base stations may provide limited voice traffic capabilities, but each is capable of gathering sufficient wireless signal characteristics from an MS within the location base station's range to facilitate locating the MS. Thus, by positioning the location base stations at known locations in a geographic region such as, for instance, on street lamp poles and road signs, additional MS location accuracy can be obtained. That is, due to the low power signal output by such location base stations, for there to be signaling control communication (e.g., pilot signaling and other control signals) between a location base station and a target MS, the MS must be relatively near the location base station. Additionally, for each location base station not in communication with the target MS, it is likely that the MS is not near to this location base station. Thus, by utilizing information received from both location base stations in communication with the target MS and those that are not in communication with the target MS, the present invention can substantially narrow the possible geographic areas within which the target MS is likely to be. Further, by providing each location base station (LBS) with a co-located stationary wireless transceiver (denoted a built-in MS above) having similar functionality to an MS, the following advantages are provided:

The paragraph beginning on page 17, line 12 has been replaced with the following paragraph:

It is also an aspect of the present invention to automatically (re)calibrate as in (6.3) above with signal characteristics from other known or verified locations. In one embodiment of the present invention,

portable location verifying electronics are provided so that when such electronics are sufficiently near a located target MS, the electronics: (i)[(I)] detect the proximity of the target MS; (ii) determine a highly reliable measurement of the location of the target MS; (iii) provide this measurement to other location determining components of the present invention so that the location measurement can be associated and archived with related signal characteristic data received from the target MS at the location where the location measurement is performed. Thus, the use of such portable location verifying electronics allows the present invention to capture and utilize signal characteristic data from verified, substantially random locations for location system calibration as in (6.3) above. Moreover, it is important to note that such location verifying electronics can verify locations automatically wherein it is unnecessary for manual activation of a location verifying process.

The paragraph beginning on page 18, line 6 has been replaced with the following paragraph:

Furthermore, a mobile location base station includes modules for integrating or reconciling distinct mobile location base station location estimates that, for example, can be obtained using the components and devices of (7.1) through (7.4) above. That is, location estimates for the mobile location base station may be obtained from: GPS satellite data, mobile location base station data provided by the location processing center, [dead reckoning] deadreckoning data obtained from the mobile location base station vehicle [dead reckoning] deadreckoning devices, and location data manually input by an operator of the mobile location base station.

The paragraph beginning on page 18, line 11 has been replaced with the following paragraph:

[   ]The location estimating system of the present invention offers many advantages over existing location systems. The system of the present invention, for example, is readily adaptable to existing wireless communication systems and can accurately locate people and/or objects in a cost effective manner. In particular, the present invention requires few, if any, modifications to commercial wireless communication systems for implementation. Thus, existing personal communication system infrastructure base stations and other components of, for example, commercial CDMA infrastructures are readily adapted to the present invention. The present invention can be used to locate people and/or objects that are not in the line-of-sight of a wireless receiver or transmitter, can reduce the detrimental effects of multipath on the accuracy of the location estimate, can potentially locate people and/or objects located indoors as well as outdoors, and uses a number of wireless stationary transceivers for location.

The present invention employs a number of distinctly different location computational models for location which provides a greater degree of accuracy, robustness and versatility than is possible with existing systems. For instance, the location models provided include not only the radius-radius/TOA and TDOA techniques but also adaptive artificial neural net techniques. Further, the present invention is able to adapt to the topography of an area in which location service is desired. The present invention is also able to adapt to environmental changes substantially as frequently as desired. Thus, the present invention is able to take into account changes in the location topography over time without extensive manual data manipulation. Moreover, the present invention can be utilized with varying amounts of signal measurement inputs. Thus, if a location estimate is desired in a very short time interval (e.g., less than approximately one to two seconds), then the present location estimating system can be used with only as much signal measurement data as is possible to acquire during an initial portion of this time interval. Subsequently, after a greater amount of signal measurement data has been acquired, additional more accurate location estimates may be obtained. Note that this capability can be useful in the context of 911 emergency response in that a first quick [course]coarse wireless mobile station location estimate can be used to route a 911 call from the mobile station to a 911 emergency response center that has responsibility for the area containing the mobile station and the 911 caller. Subsequently, once the 911 call has been routed according to this first quick location estimate, by continuing to receive additional wireless signal measurements, more reliable and accurate location estimates of the mobile station can be obtained.

The paragraph beginning on page 19, line 5 through page 19, line 19 has been replaced with the following paragraph:

At a more general level, it is an aspect of the present invention to demonstrate the utilization of various novel computational paradigms such as:

(8.1) providing a multiple hypothesis computational architecture (as illustrated best in [Fig. 8] Figs. 8) wherein the hypotheses are:

(8.1.1) generated by modular independent hypothesizing computational models;

(8.1.2) the models are embedded in the computational architecture in a manner wherein the architecture allows for substantial amounts of application specific processing common or generic to a plurality of the models to be straightforwardly incorporated into the computational architecture;

(8.1.3) the computational architecture enhances the hypotheses generated by the models both according to past performance of the models and according to application specific constraints and heuristics without requiring feedback loops for adjusting the models;

(8.1.4) the models are relatively easily integrated into, modified and extracted from the computational architecture;

(8.2) providing a computational paradigm for enhancing an initial estimated solution to a problem by using this initial estimated solution as, effectively, a query or index into an historical data base of previous solution estimates and corresponding actual solutions for deriving an enhanced solution estimate based on past performance of the module that generated the initial estimated solution.

The paragraph beginning on page 20, line 19 has been replaced with the following paragraph:

In other embodiments of the present invention, a fast, [abeit]albeit less accurate location estimate may be initially performed for very time critical location applications where approximate location information may be required. For example, less than 1 second response for a mobile station location embodiment of the present invention may be desired for 911 emergency response location requests. Subsequently, once a relatively [course]coarse location estimate has been provided, a more accurate most likely location estimate can be performed by repeating the location estimation processing a second time with, e.g., additional with measurements of wireless signals transmitted between a mobile station to be located and a network of base stations with which the mobile station is communicating, thus providing a second, more accurate location estimate of the mobile station.

The paragraph beginning on page 21, line 1 has been replaced with the following paragraph:

Note that in some embodiments of the present invention, since there is a lack of sequencing between the FOMs and subsequent processing of location hypotheses, the FOMs can be incorporated into an expert system, if desired. For example, each FOM may be activated from an antecedent of an expert system rule. Thus, the antecedent for such a rule can evaluate to TRUE if the FOM outputs a location hypothesis, and the consequent portion of such a rule may put the output location hypothesis on a list of location hypotheses occurring in a particular time window for subsequent processing by the location center. Alternatively, activation of the FOMs may be in the consequents of such expert system rules.

That is, the antecedent of such an expert system rule may determine if the conditions are appropriate for invoking the FOM(s) in the rule's consequent.

The paragraph beginning on page 21, line 8 has been replaced with the following two paragraphs. Note that the only difference here is the commencement of a new paragraph at –Further features and advantages–.

Of course, other software architectures may also to used in implementing the processing of the location center without departing from scope of the present invention. In particular, object-oriented architectures are also within the scope of the present invention. For example, the FOMs may be object methods on an MS location estimator object, wherein the estimator object receives substantially all target MS location signal data output by the signal filtering subsystem. Alternatively, software bus architectures are contemplated by the present invention, as one skilled in the art will understand, wherein the software architecture may be modular and facilitate parallel processing.

Further features and advantages of the present invention are provided by the figures and detailed description accompanying this invention summary.

The paragraph beginning on page 22, line 5 has been replaced with the following paragraph:

Fig. 3 provides a typical example of how the statistical power budget is calculated in design of a Commercial Mobile Radio Service Provider (CMRS) network.

The paragraph beginning on page 22, line 14 has been replaced with the following paragraph:

Figs. 9A and 9A is a high level data structure diagram describing the fields of a location hypothesis object generated by the first order models 1224 of the location center.

The paragraph beginning on page 23, line 16 has been replaced with the following paragraph:

Figs. 23[a]A through 23[b]C present a high level flowchart of the steps performed by function, "GET_DIFFERENCE_MEASUREMENT," for updating location signatures in the location signature data base 1320; note, this flowchart corresponds to the description of this function in APPENDIX C.